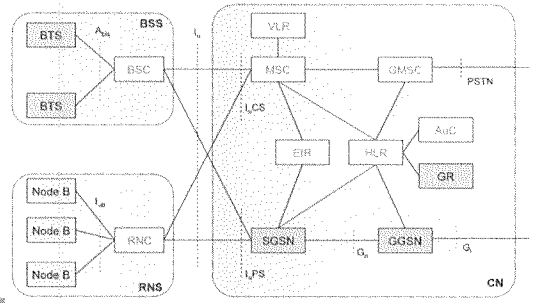
Cellular networks

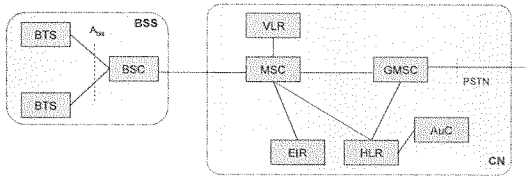
- GSM architecture



Circuit Switched Domain (CSD)

Cellular networks

- GSM network architecture



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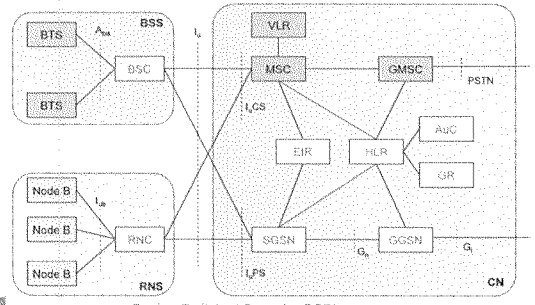
The (r)evolution of wireless network architectures and protocols

Ingrid Moerman
IBBT - Ghent University

Cellular networks

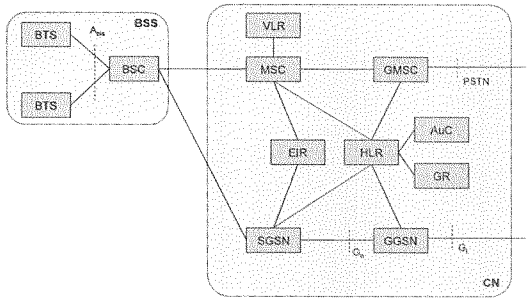
- UMTS network architecture (release 1999)



Packet Switched Domain (PSD)

Cellular networks

- GPRS network architecture



Wireless networks today

- A myriad of available wireless network technologies
  - building on proprietary on standardized radio technologies

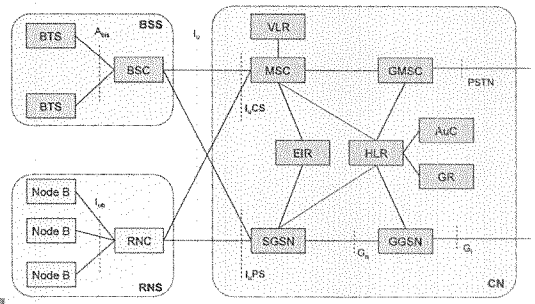
- Many non-interoperable solutions
  - different architectures
  - different protocols
  - assumption of homogeneous nodes: same protocol stack on all nodes
- Tuned for a specific application

Cellular networks: UMTS releases

Version	Released	Info
Release 98	1998	This and earlier releases specify pre-3G GSM networks
Release 99	2000 Q1	Specified the first UMTS 3G networks Incorporating a CDMA air interface
Release 4	2001 Q2	Originally called the Release 2000 Added QoS architecture for PS domain
Release 5	2002 Q1	GSM/GPRS core network replaced by all-IP-core Introduced IMS (IP Multimedia Subsystem) Introduced HSDPA (High Speed Downlink Data Packet Access)
Release 6	2004	Integrated operation with Wireless LAN networks Adds HSUPA (High Speed Uplink Data Packet Access) Use of Multiple Input Multiple Output antennas (MIMO) MBMS (Multimedia Broadcast Multicast Services → Mobile TV) Enhancements to IMS such as Push to Talk over Cellular (PoC)
Release 7	2007 Q4	Further radio technology improvements (HSPA+) Continued convergence with IP technology (IPv6, IP security, QoS, VoIP) Contactless front-end interface (Near Field Communication enabling operators to deliver contactless services like Mobile Payments)
Release 8	In progress (expected 2009)	LTE (Long Term Evolution) All-IP Network (SAE or System Architecture Evolution) refactoring of UMTS as an entirely IP based fourth-generation network

Cellular networks

- UMTS network architecture (release 1999)



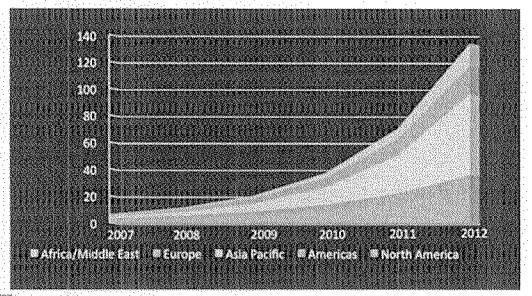
Outline

- Wireless networks today
  - Cellular networks
  - Wireless MAN
  - Wireless LAN
  - Wireless PAN (short range)
- Use of wireless networks
  - Wireless sensor networks
  - Ubiquitous networks
  - Intelligent Transport Systems
- Wireless networks tomorrow
  - Internet of things
  - No more IP, no more layers?
  - Network virtualization
  - ...

Wireless MAN: WiMAX or IEEE802.16

WiMAX Forecast

- 133 M users by 2012



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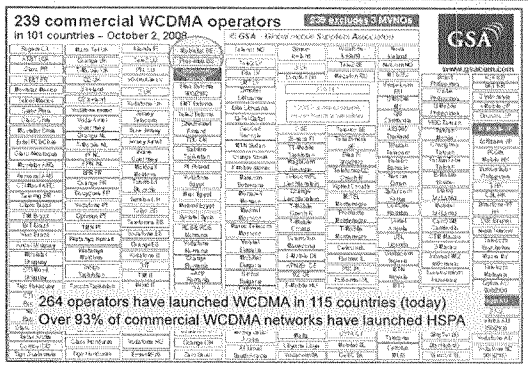
Cellular networks: UMTS deployments



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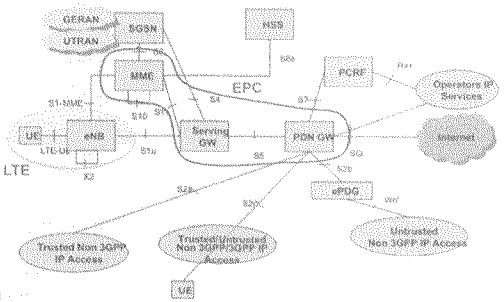
Cellular networks

SAE (System Architecture Evolution) - EPC (Evolved Packet Core)



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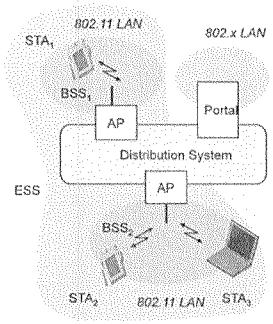
Wireless LAN: WiFi or IEEE 802.11



Infrastructure network

- Station (STA)
  - terminal with access mechanisms to the wireless medium and radio contact to the access point
- Access Point (AP)
  - station integrated into the wireless LAN and the distribution system
- Basic Service Set (BSS)
  - AP and group of stations using the same radio frequency
- Distribution System
  - (wired) interconnection network to form one logical network (EES: Extended Service Set) based on several BSSs
- Portal
  - bridge to other (wired) networks

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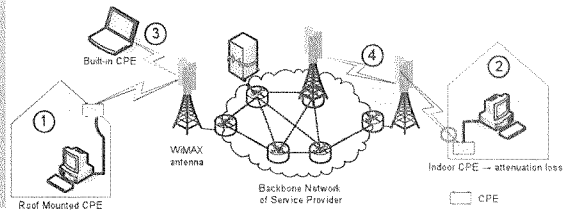
Wireless MAN: WiMAX or IEEE802.16

- Replacement of last mile cabling
  1. roof mounted CPE
  2. indoor CPE
  3. WiMAX compatible hardware is built directly in the mobile device
  4. WiMAX is used as a replacement for a part of the backbone



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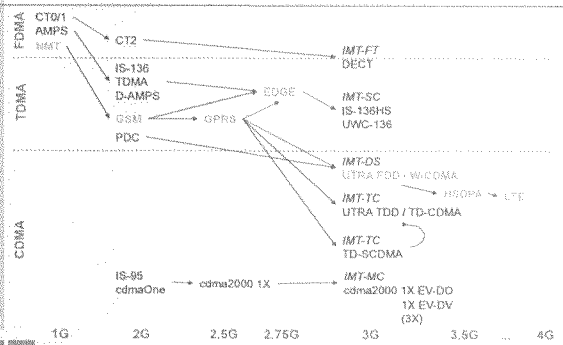
Cellular networks : evolution



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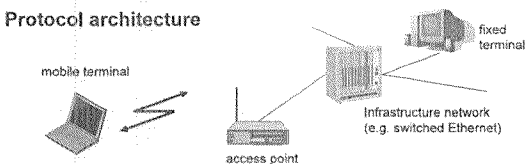
Wireless LAN: WiFi or IEEE 802.11

Protocol architecture



application		application
TCP		TCP
IP		IP
LLC	bridge: LLC	LLC
802.11 MAC	802.11 MAC / 802.3 MAC	802.3 MAC
802.11 PHY	802.11 PHY / 802.3 PHY	802.3 PHY

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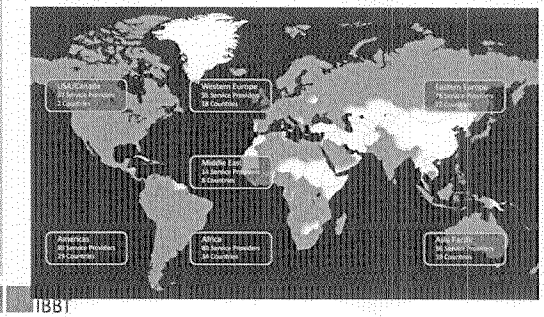
Wireless MAN: WiMAX or IEEE802.16

- (pre) WiMAX deployments
  - 407 trials and deployments in 133 countries



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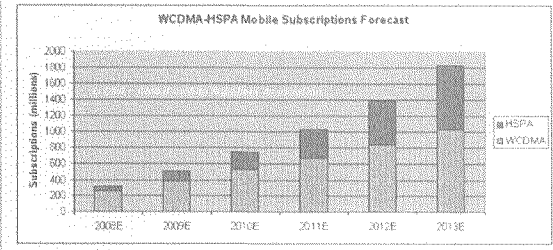
Cellular networks: UMTS users



Today

GSM/UMTS: 3545 M subscribers

UMTS: 287 M subscribers

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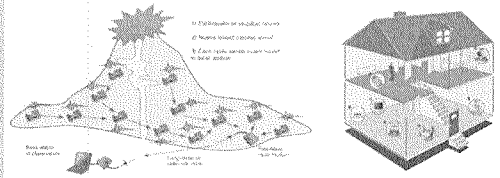
Wireless Sensor and Actuator Network (WSAN)

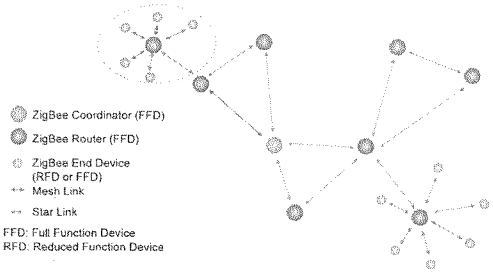


homogeneous nodes
sensors only
unidirectional communication to sink
unreliable network

heterogeneous nodes
sensor & actuators
more complex communication patterns
reliability & QoS support

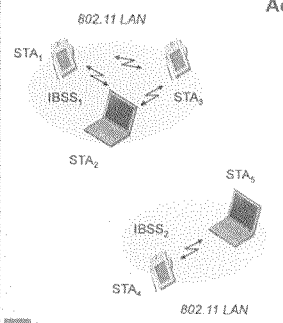
Wireless PAN: ZigBee or IEEE 802.15.4

ZigBee network model



ZigBee™ Alliance
Wireless Control That Simply Works

Wireless LAN: WiFi or IEEE 802.11



Ad Hoc network

Direct communication within a limited range

- Station (STA)
  - terminal with access mechanisms to the wireless medium
- Independent Basic Service Set (IBSS)
  - group of stations using the same radio frequency

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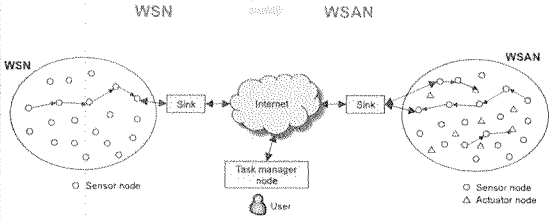
Wireless Sensor and Actuator Network (WSAN)



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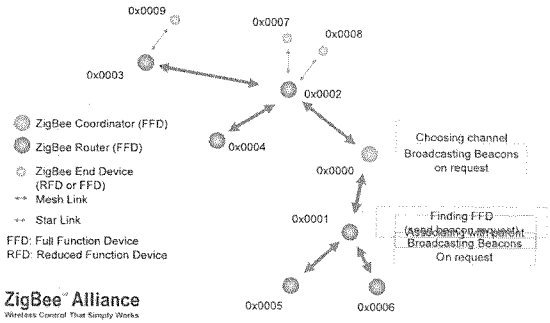
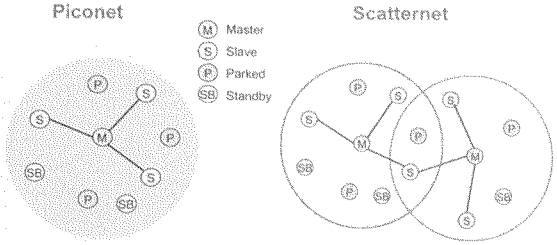
Wireless PAN: ZigBee or IEEE 802.15.4

ZigBee network formation



ZigBee™ Alliance
Wireless Control That Simply Works

Wireless PAN: Bluetooth or IEEE 802.15.1



Controlled by master
Only 8 active devices!

Bluetooth not suited for large (ad hoc) networks

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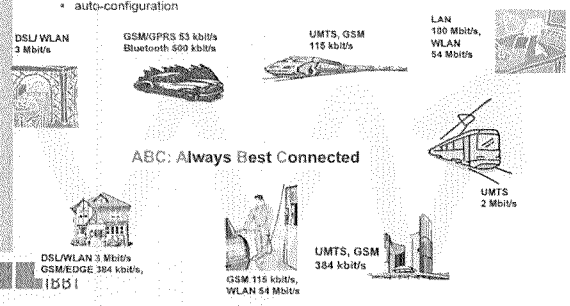
Ubiquitous networks

- Challenges
  - horizontal and vertical handover
  - uninterrupted services
  - auto-configuration



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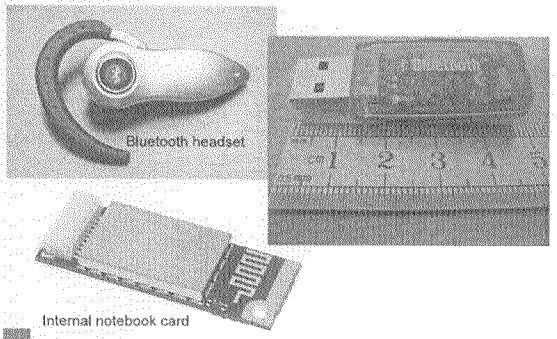
  - No more IP, no more layers?
  - Network virtualization
  - ...

Wireless PAN: Bluetooth or IEEE 802.15.1



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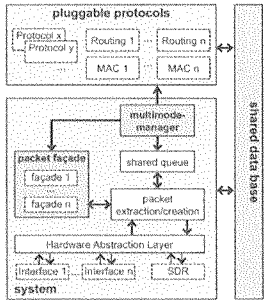
Modular protocol architecture: no layers!

- System-created packet headers
  - no duplicate headers fields
  - compatible with legacy systems
  - protocols are independent of the underlying packet structure
- Energy-efficient
  - different information exchanges are aggregated in the same packet
- Smaller protocols
  - buffers are shared, and are provided by the system
  - no code required for header manipulations
- Heterogeneous environments
  - system components and protocols can dynamically be removed or added
  - dynamic run-time selection of the best routing/MAC protocol



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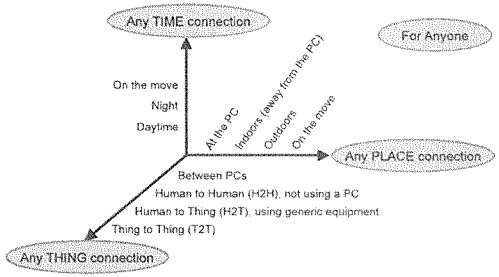
The Internet of things

- The 4A vision (ITU)
  - AnyTIME, Any PLACE connectivity for Anyone



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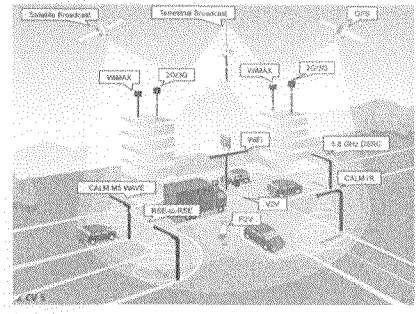
Source: ITU Internet Reports 2005: The Internet of Things 34

Intelligent Transport Systems (ITS)

Efficient & safe transport through use of many technologies



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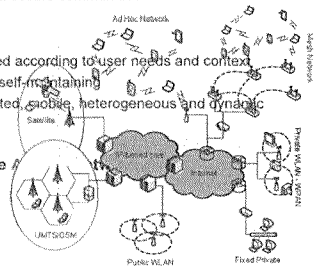
Network virtualization

- Network virtualization
  - 4G all-IP network = carrier that provides end-to-end connectivity
  - On top: multiple virtual networks that logically structure the network and its services into small secure communities
- Ad hoc
  - Formed when needed according to user needs and context
  - Self-organizing and self-maintaining
  - Dealing with distributed, mobile, heterogeneous and dynamic characteristics
- VPAN (Virtual Private



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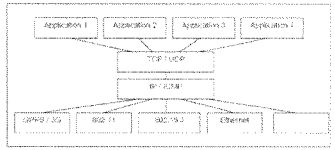
Standards-setting and interoperability

- IETF vision
  - Internet of things = IP for Smart Objects (IPSO)
  - Solution: IP as an open an flexible standard



- IP = open (IETF is open standardization organization)
- IP = lightweight (only few Kbytes RAM/ROM required)
- IP = versatile (support of many diverse applications)
- IP = ubiquitous (any OS, easy IP access, unique addressing)
- IP = scalable (IPv6 expanded address space →6lowpan)
- IP = manageable (DNS, DHCP, SNMP, …)
- IP = stable (nearly 30 years existence → well-established knowledge)
- IP = end-to-end (no need for complex protocol gateways)

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Source: IP for Smart Objects – White paper #1, IPSO Alliance 35

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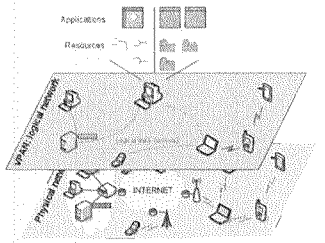
Network virtualization

- Virtual Private Ad Hoc Network (VPAN)
  - A secure and self-organizing virtual overlay network of distributed nodes deploying ad hoc network techniques and private addressing
  - Secure: both in terms of networking and applications and services



VPAN data

Encrypted and/or tunneled VPAN data

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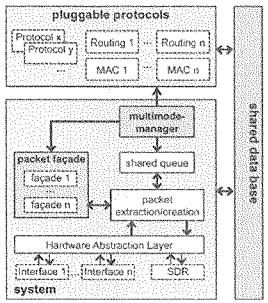
Modular protocol architecture: no layers!

- Information driven architecture
- Redefinition of the role of protocols:
  - ✓ Protocol = Algorithm + Information exchanges
  - ✗ Protocol != buffer creation or header definition
- Protocols only exchange information with the system
- The system creates the data packets.



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Wireless networks tomorrow

- Observation
  - Wireless networks are **heterogeneous!**
    - wireless/wired technologies
    - device capabilities
      - interfaces, power supply, energy safe mode, memory, processing, mobility…
    - services
      - data rate, latency, reliability, continuous/intermittent/periodic …
- Need for more flexible architectures
  - supporting diverse services
  - incorporating heterogeneous devices
  - allowing heterogeneous access
  - **autonomous adaptation**

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Summary

- A myriad of available wireless network technologies
- Need for flexible network architectures coping with heterogeneity
- Future =
  - Evolution: IP-based
  - Revolution: no IP, no layers
  - Virtualization